# 1A Linear Li-Ion/Polymer Charger IC with Integrated FET and Charger Timer

## DESCRIPTION

The EUP8090 series are highly integrated single cell Li-Ion/Polymer battery charger IC designed for handheld devices. This charger is designed to work with various types of AC adapters capable of operating with an input voltage as low as 2.65V.

The EUP8090 operates as a linear charger and charges the battery in three phases: trickle current, constant current, and constant voltage. When AC-adapter is applied, an external resistor sets the magnitude of the charge current, which may be programmed up to 1A with TDFN10 package and a current-limited adapter for lowest power dissipation.

The EUP8090 features thermal regulation loop to control charge current to keep safe operation when PCB lacked of enough heat-sinking. A programmable charge timer provides a backup safety for termination. The EUP8090 automatically re-starts the charge if the battery voltage falls below an internal threshold and automatically enters sleep mode when DC supplies are removed. No external sense resistor or blocking diode is required for charging.

## FEATURES

- Very Low Power Dissipation
- Accepts Multiple Types of Adapters Power
- Integrated Power FET and Current Sensor for Up to 1A Charge Applications
- Guaranteed to Operate at 2.65V After Start-Up
- Charge Termination by Minimum Current and Time
- Precharge Conditioning With Safety Timer
- Reverse Leakage Protection Prevents Battery Drainage
- Charge Current Thermal Regulation
- Status Outputs for LED or System Interface Indicates Charge Conditions
- Automatic Sleep Mode for Low-Power Consumption
- Available in 3mm×3mm TDFN-10 Package
- RoHS Compliant and 100% Lead (Pb)-Free Halogen-Free

## APPLICATIONS

- PDAs, Cell Phones and Smart Phones
- Portable Instruments.
- Stand-Alone Charger.
- USB Bus Powered Charger.

## Typical Application Circuit

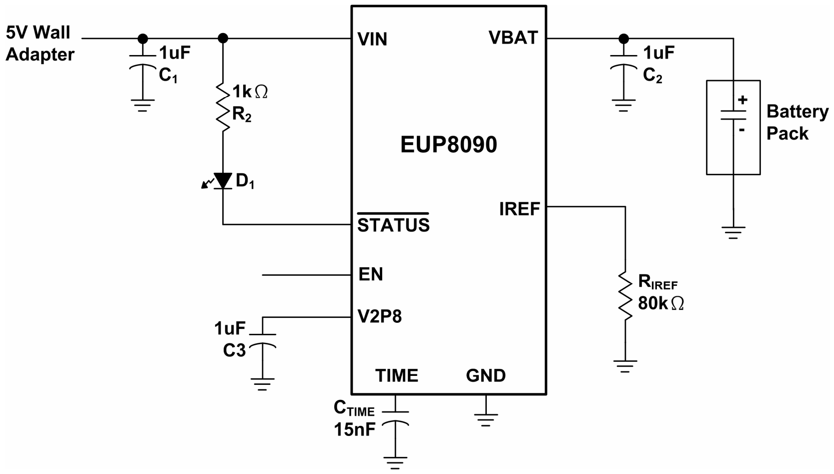
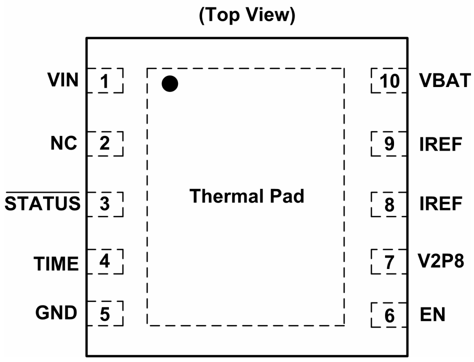



**Figure 1.**

## Pin Configurations

| Package Type | Pin Configurations |
|---|---|
| TDFN-10 |   |

## Pin Description

| PIN | TDFN-10 | DESCRIPTION |
|---|---|---|
| VIN | 1 | VIN is the input power source. Connect to a wall adapter. |
| NC | 2 | No connect. |
| $\overline{\text{STATUS}}$ | 3 | STATUS is an open-drain output indicating charging and inhibit states. The STATUS pin is pulled LOW when the charger is charging a battery. |
| TIME | 4 | The TIME pin determines the oscillation period by connecting a timing capacitor between this pin and GND.<br>The oscillator also provides a time reference for the charger. |
| GND | 5 | GND is the connection to system ground. |
| EN | 6 | EN is the enable logic input. Connect the EN pin to LOW to disable the charger or leave it floating to enable the charger. |
| V2P8 | 7 | This is a 2.8V reference voltage output. This pin outputs a 2.8V voltage source when the input voltage is above POR threshold and outputs zero otherwise. The V2P8 pin can be used as an indication for adapter presence. |
| IREF | 8,9 | This is the programming input for the constant charging current. |
| VBAT | 10 | VBAT is the connection to the battery. Typically a 1µF Tantalum capacitor is needed for stability when there is no battery attached. When a battery is attached, only a 0.1µF ceramic capacitor is required. |

## Ordering Information

| Order Number | Package Type | Marking | Operating Temperature Range | VBAT (V) | TIMEOUT |
|---|---|---|---|---|---|
| EUP8090JIR1 | TDFN-10 | xxxxx<br>8090D<br>3H | -20 °C to 70°C | 4.2 | YES |

EUP8090 □ □ □ □

Lead Free Code
1: Lead Free, Halogen Free

Packing
R: Tape& Reel

Operating temperature range
I: Industry Standard

Package Type
J: TDFN-10

## Block Diagram

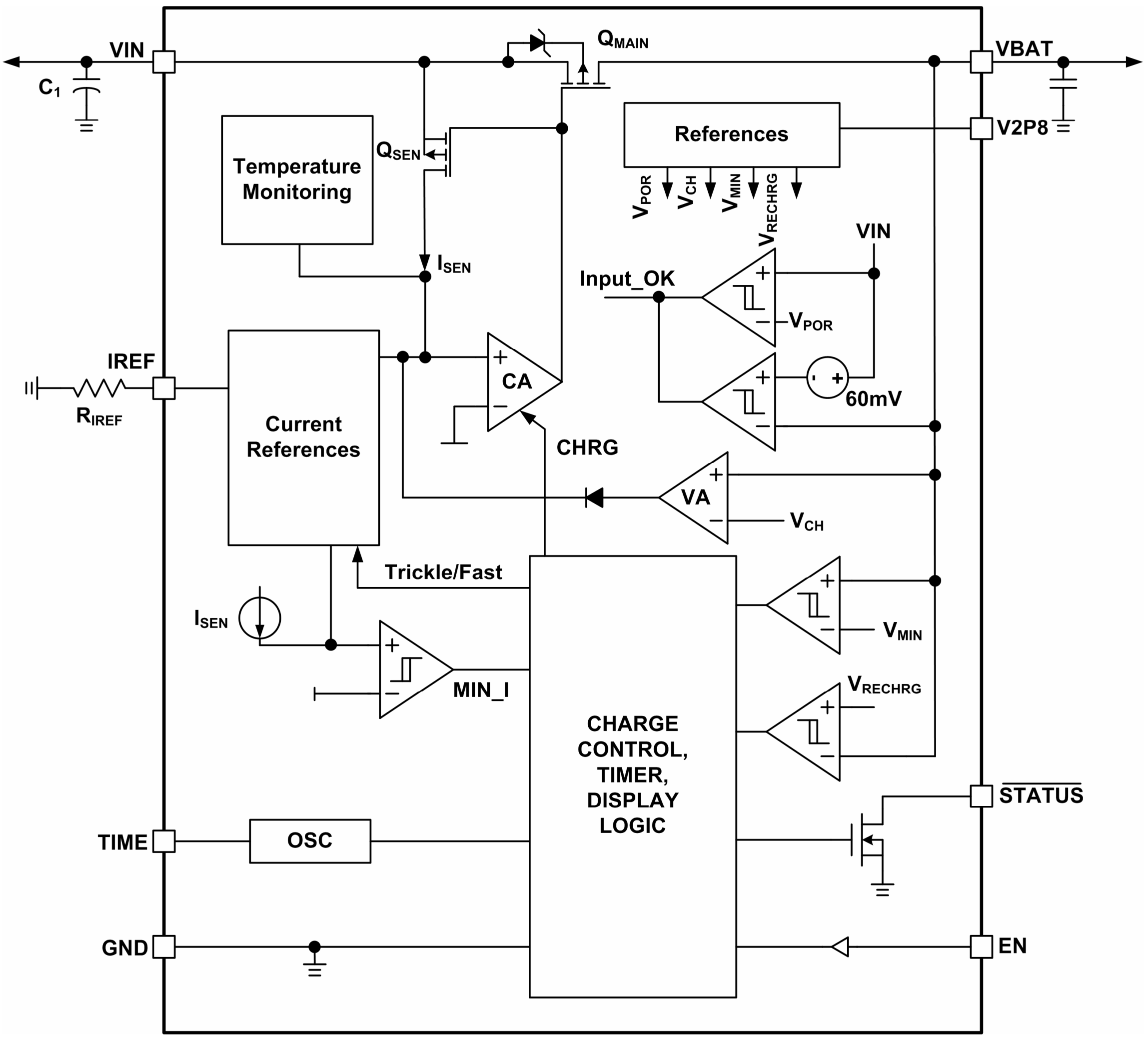



**Figure 2.**

## Absolute Maximum Ratings

- Supply Voltage (VIN) ------------------------------------------------------------------------------ -0.3V to 7V
- Output Pin Voltage (VBAT) ------------------------------------------------------------------------ -0.3V to 5.5V
- Signal Input Voltage (EN,TIME, IREF) ------------------------------------------------------------ -0.3V to 7V
- Output Pin Voltage ( $\overline{STATUS}$ ) ----------------------------------------------------------------- -0.3V to 5.5V
- Junction temperature range, $T_J$ ------------------------------------------------------------------------ 150°C
- Storage temperature range, Tstg ---------------------------------------------------------- -65°C to 150°C
- Lead temperature (soldering, 10s) ----------------------------------------------------------------- 260°C
- ESD protection ------------------------------------------------------------------------------------------ 2kV

## Dissipation Ratings

| Package | $\theta_{JA}$ | $T_A$ < 40°C Power Rating | Derating Factor Above $T_A$ =25°C |
|---|---|---|---|
| TDFN-10 | 48°C/W | 1.5W | 0.0208 W/°C |

## Recommended Operating Conditions

| | Min. | Max. | Unit |
|---|---|---|---|
| Supply voltage ,VIN | 4.3 | 6.5 | V |
| Ambient Temperature Range | -20 | 70 | °C |

## Electrical Characteristics

Typical values are tested at VIN = 5V and +25°C Ambient Temperature, maximum and minimum values are guaranteed over 0°C to +70°C Ambient Temperature with a supply voltage in the range of 4.3V to 6.5V, unless otherwise noted.

| Symbol | Parameter | Conditions | EUP8090 | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min. | Typ. | Max. | |
| **POWER-ON RESET** | | | | | | |
| | Rising VIN Threshold | | 3.0 | 3.4 | 4.0 | V |
| | Falling VIN Threshold | | 2.25 | 2.4 | 2.65 | V |
| **STANDBY CURRENT** | | | | | | |
| $I_{STANDBY}$ | VBAT Pin Sink Current | VIN floating or EN = LOW | - | - | 3.0 | μA |
| $I_{VIN}$ | VIN Pin Supply Current | VBAT floating and EN pulled low | - | 30 | - | μA |
| $I_{VIN}$ | VIN Pin Supply Current | VBAT floating and EN floating | - | 1 | - | mA |
| **VOLTAGE REGULATION** | | | | | | |
| $V_{CH}$ | Output Voltage | | 4.158 | 4.20 | 4.242 | V |
| | Dropout Voltage | VBAT = 3.7V, 0.5A, 3X3 package | - | 170 | - | mV |
| **CHARGE CURRENT** | | | | | | |
| $I_{CHARGE}$ | Constant Charge Current | VBAT = 3.7V | 0.9 | 1.0 | 1.1 | A |
| $I_{TRICKLE}$ | Trickle Charge Current | VBAT = 2.0V | - | 110 | - | mA |
| EOC | End-of-Charge Threshold | | 80 | 115 | 140 | mA |

## Electrical Characteristics (continued)

Typical values are tested at VIN = 5V and +25°C Ambient Temperature, maximum and minimum values are guaranteed over 0°C to +70°C Ambient Temperature with a supply voltage in the range of 4.3V to 6.5V, unless otherwise noted.

| Symbol | Parameter | Conditions | EUP8090 | | | Unit |
|---|---|---|---|---|---|---|
| | | | Min. | Typ. | Max. | |
| **RECHARGE THRESHOLD** | | | | | | |
| $V_{RECHRG}$ | Recharge Voltage Threshold | | - | 4.0 | - | V |
| **TRICKLE CHARGE THRESHOLD** | | | | | | |
| $V_{MIN}$ | Trickle Charge Threshold Voltage | | 2.7 | 2.85 | 3 | V |
| **OSCILLATOR** | | | | | | |
| $T_{OSC}$ | Oscillation Period | $C_{TIME}$ = 15nF | 2.4 | 3 | 3.6 | ms |
| **LOGIC INPUT AND OUTPUT** | | | | | | |
| | STATUS Sink Current | Pin Voltage = 0.8V | 5 | - | - | mA |

(1) $$I_{O(OUT)} = \left(\frac{10^5 \times 0.8V}{R_{IREF}}\right)$$

(2) $$I_{O(PRECHG)} = \left(\frac{10^4 \times 0.8V}{R_{IREF}}\right)$$

(3) $$I_{O(EOC)} = \left(\frac{10^4 \times 0.8V}{R_{IREF}}\right)$$

## Application Information

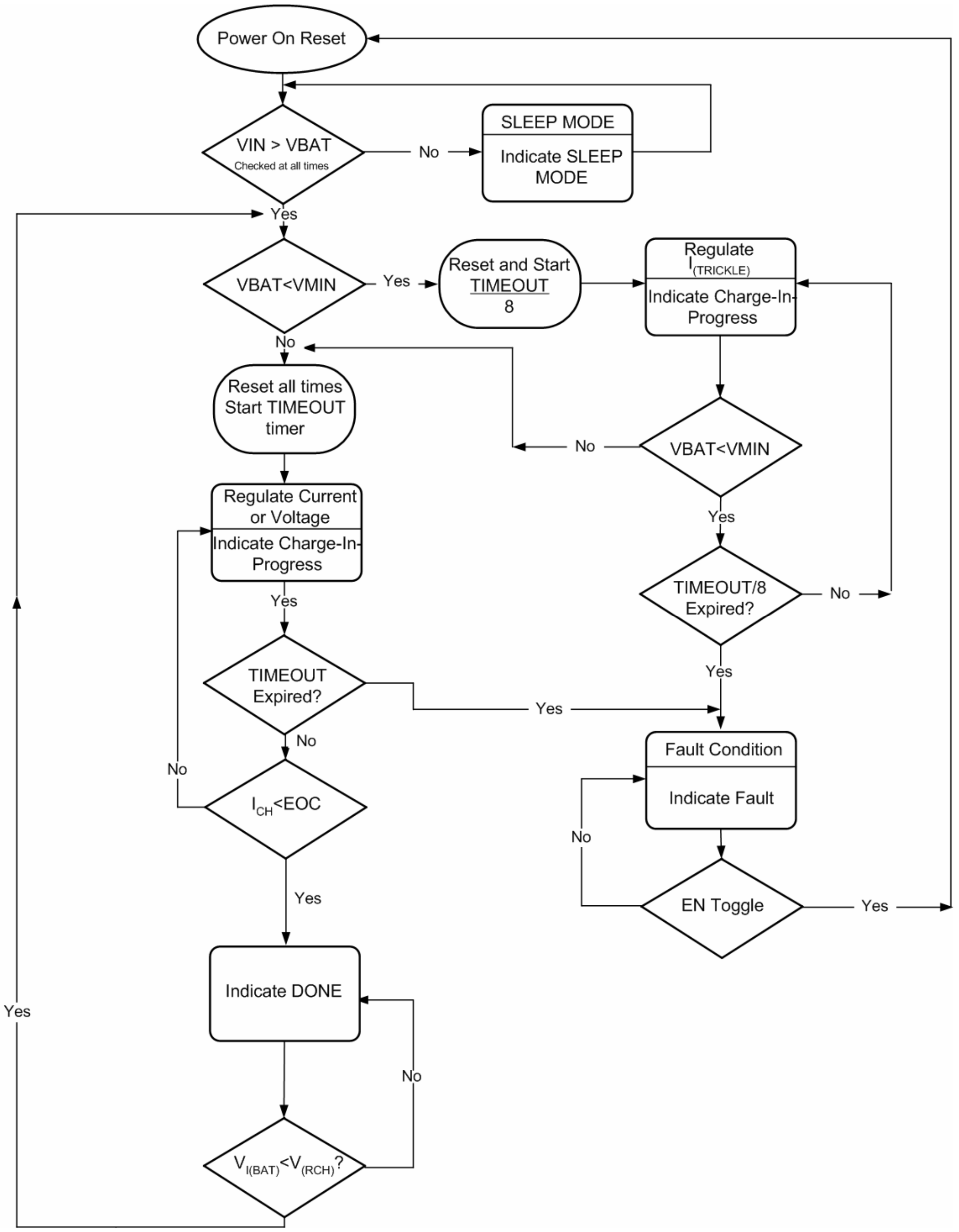



**Figure 3. Operational Flow Chart**

## Typical Operating Characteristics

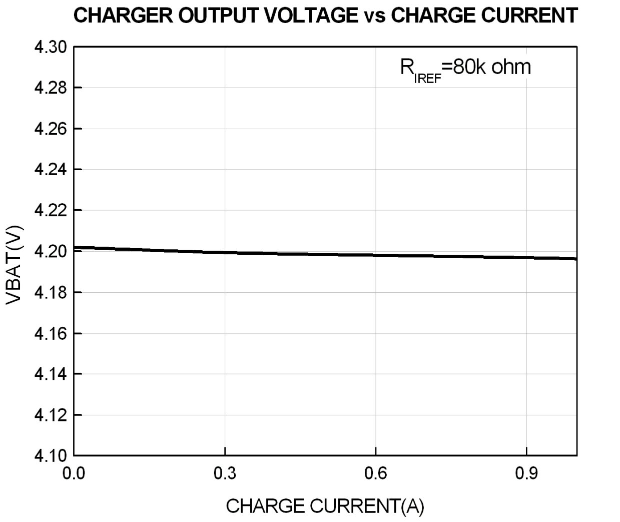



**Figure 4.**

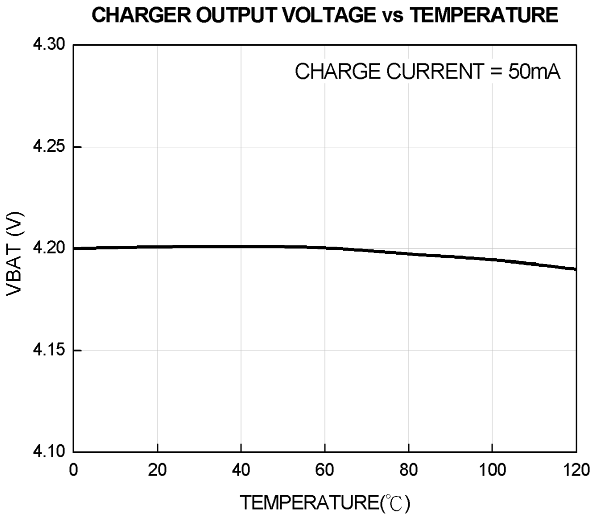



**Figure 5.**

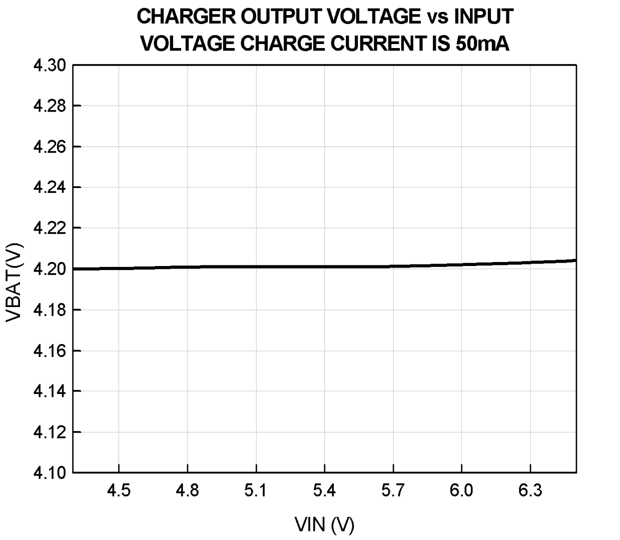



**Figure 6.**

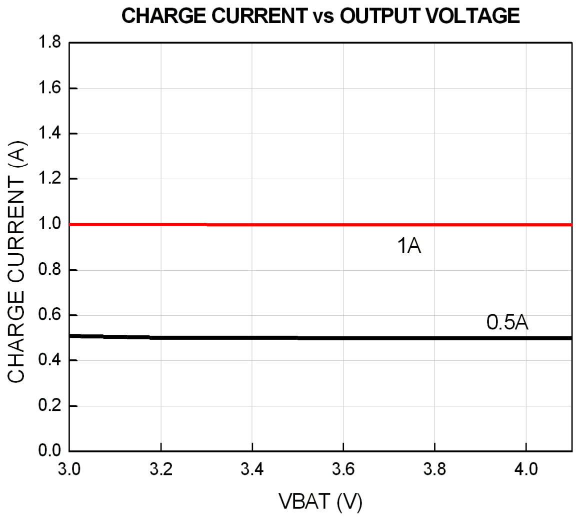



**Figure 7.**

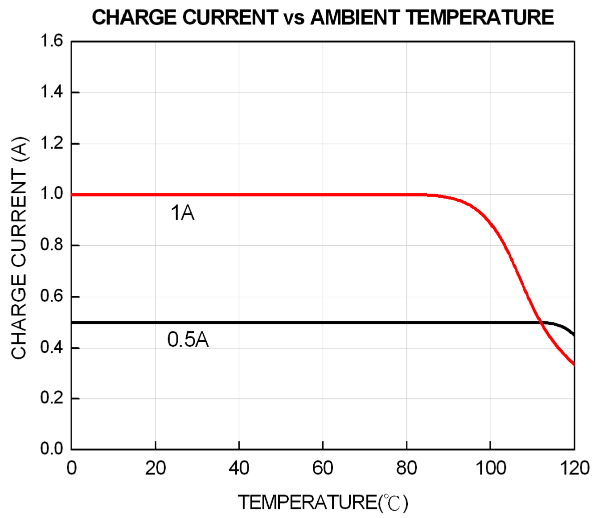



**Figure 8.**

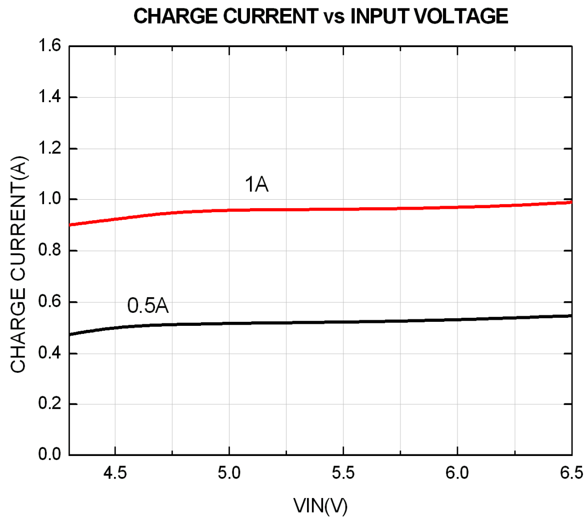



**Figure 9.**

## Typical Operating Characteristics (continued)

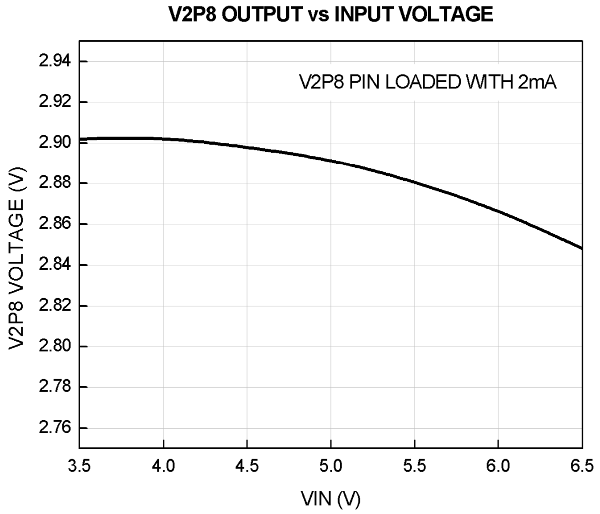



Figure 10.

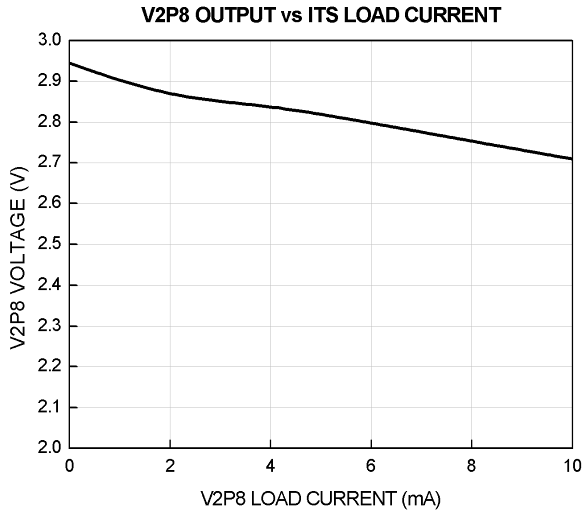



Figure 11.

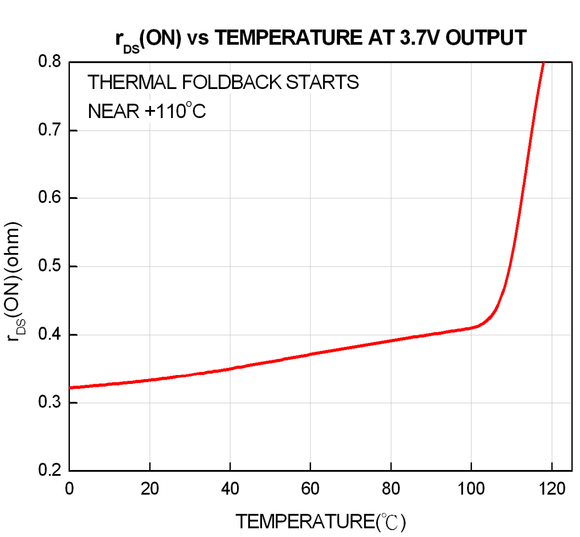



Figure 12.

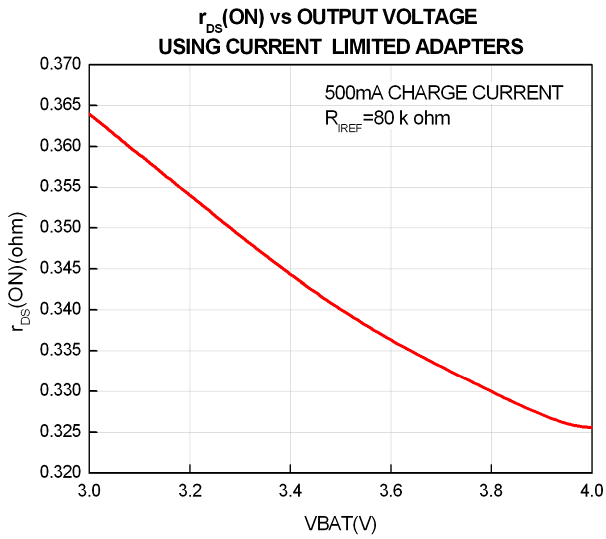



Figure 13.

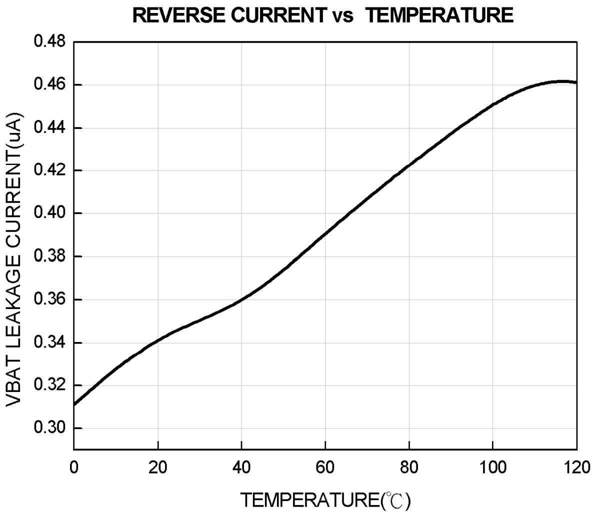



Figure 14.

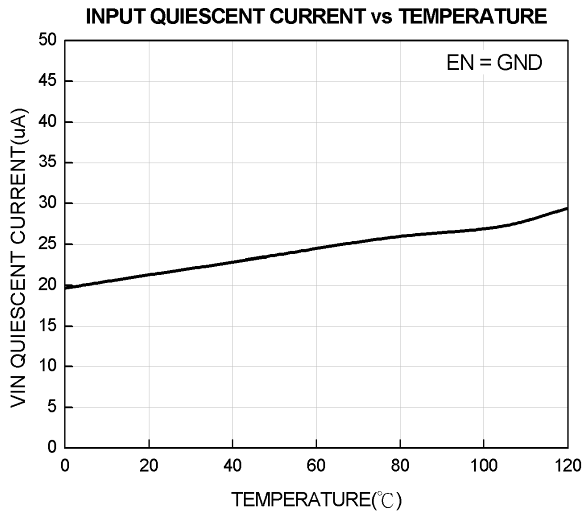



Figure 15.

## Typical Operating Characteristics (continued)

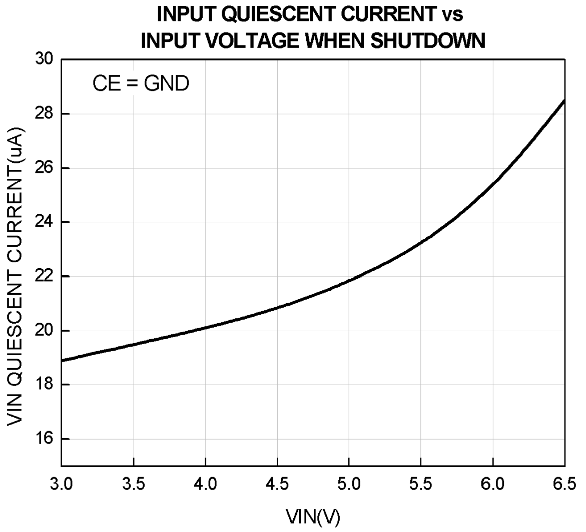



**Figure 16.**

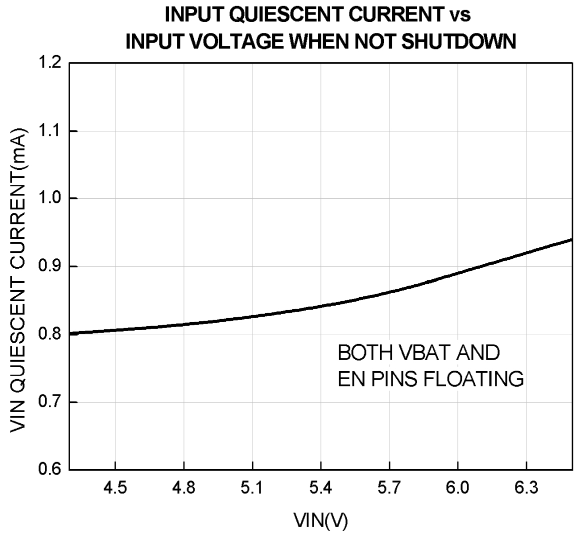



**Figure 17.**

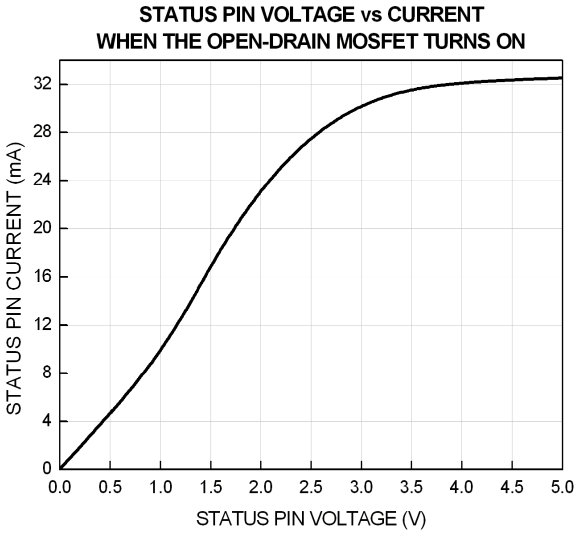



**Figure 18.**

## OPERATION

The EUP8090 is an integrated charger for single-cell Li-ion or Li-polymer batteries. As a linear charger, the EUP8090 charges a battery in the popular constant current (CC) and constant voltage (CV) profile. The constant charge current $I_{REF}$ is programmable up to 1A with an external resistor or a logic input. The charge voltage $V_{CH}$ has 1% accuracy over the entire recommended operating condition range. A thermal-regulation feature removes the thermal concern typically seen in linear chargers. The charger reduces the charge current automatically as the IC internal temperature rises above +110°C to prevent further temperature rise. The thermal-regulation feature guarantees safe operation when the printed circuit board (PCB) is space limited for thermal dissipation.

Figure 19 shows the typical charge curves in a traditional linear charger powered with a constant-voltage adapter. From the top to bottom, the curves represent the constant input voltage, the battery voltage, the charge current and the power dissipation in the charger. The power dissipation $P_{CH}$ is given by the following equations:

$$P_{CH} = (V_{IN} - V_{BAT}) \times I_{CHARGE} \qquad (1)$$

where $I_{CHARGE}$ is the charge current. The maximum power dissipation occurs during the beginning of the CC mode. The maximum power the IC is capable of dissipating is dependent on the thermal impedance of the printed-circuit board (PCB). Figure 19 shows, with dotted lines, two cases that the charge currents are limited by the maximum power dissipation capability due to the thermal regulation.

When using a current-limited adapter, the thermal situation in the EUP8090 is totally different. Figure 19 shows the typical charge curves when a current-limited adapter is employed.

The operation requires the $I_{REF}$ to be programmed higher than the limited current $I_{LIM}$ of the adapter, as shown in Figure 20. The key difference of the charger operating under such conditions occurs during the CC mode. The adapter current is limited, the actual output current will never meet what is required by the current reference. Therefore, the main MOSFET becomes a power switch instead of a linear regulation device. The power dissipation in the CC mode becomes:

$$P_{CH} = R_{DS(ON)} \times I_{CHARGE}^{2} \qquad (2)$$

where $R_{DS(ON)}$ is the resistance when the main MOSFET is fully turned on. This power is typically much less than the peak power in the traditional linear mode.

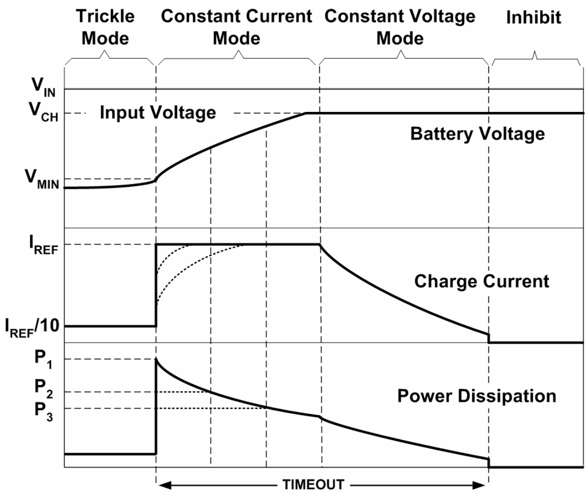



**Figure 19. Typical Charge Curves Using a Constant-Voltage Adapter**

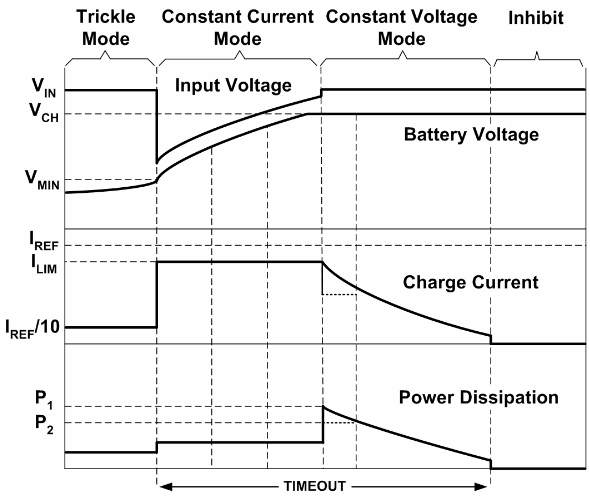



**Figure 20. Typical Charge Curves Using a Current Limited Adapter**

### Battery Pre-Conditioning

During a charge cycle if the battery voltage is below the $V_{(MIN)}$ threshold, the EUP8090 applies a precharge current, $I_{TRICKLE}$, to the battery. This feature revives deeply discharged cells. The resistor connected between the IREF and GND, $R_{IREF}$, determines the precharge rate.

$$I_{REF} = \frac{0.8V \times 10^4}{R_{IREF}} \qquad (3)$$

The EUP8090 activates a safety timer, $I_{TRICKLE}$, during the conditioning phase. If $V_{MIN}$ threshold is not reached within the timer period, the EUP8090 turns off the charger.

### Battery Charge Current

The EUP8090 offers on-chip current regulation with programmable set point. The resistor connected between the IREF and GND, $R_{IREF}$, determines the AC charge rate.
There is ways to program the charge current:
using the $R_{IREF}$ as shown in the Typical Applications.

The voltage of IREF is regulated to a 0.8V reference voltage when not driven by any external source. The charging current during the constant current mode is 100,000 times that of the current in the $R_{IREF}$ resistor. Hence, depending on how IREF pin is used, the charge current is,

$$IREF = \left\{ \frac{0.8V}{R_{IREF}} \times 10^5 (A) \qquad R_{IREF} \right. \qquad (4)$$

### Battery Voltage Regulation

The voltage regulation feedback is through the VBAT pin. This input is tied directly to the positive side of the battery pack. The EUP8090 monitors the battery pack voltage between the VBAT and GND pins. When the battery voltage rises to $V_{O(REG)}$ threshold, the voltage regulation phase begins and the charging current begins to taper down.
As a safety backup, the EUP8090 also monitors the charge time in the charge mode. If charge is not terminated within this time period, TIMEOUT, the EUP8090 turns off the charger.

### End-of-Charge (EOC) Current

The end-of-charge current C/10 sets the level at which the charger starts to indicate the end of the charge with the STATUS pin, as shown in Figure 21. The charger actually does not terminate charging until the end of the TIMEOUT, as described in the Total Charge Time section.

### Recharge

After End-of-charge, the EUP8090 re-starts the charge once the voltage on the VBAT pin falls below the $V_{(RCH)}$ threshold. This feature keeps the battery at full capacity at all times.

### Power on Reset (POR)

The EUP8090 resets itself as the input voltage rises above the POR rising threshold. The V2P8 pin outputs a 2.8V voltage, the internal oscillator starts to oscillate, the internal timer is reset, and the charger begins to charge the battery.

The EUP8090 has a typical rising POR threshold of 3.4V and a falling POR threshold of 2.4V.
Signals in a charge cycle are illustrated in Figure 21.

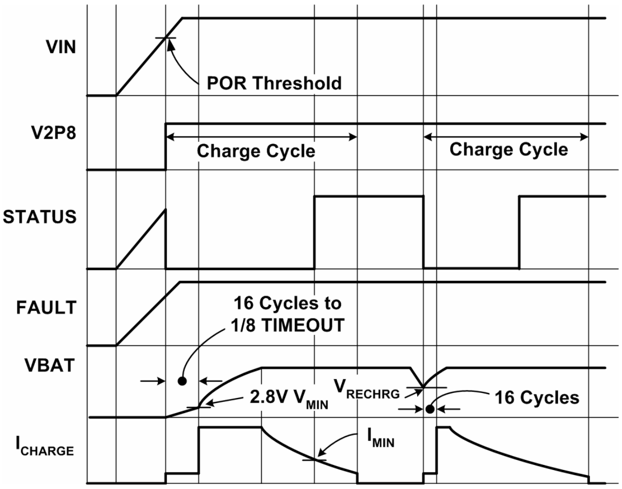



**Figure 21. Operation Waveforms**

The following events initiate a new charge cycle:
- POR,
- the battery voltage drops below a recharge threshold after completing a charge cycle,
- or, the EN pin is toggled from GND to floating.

### Sleep Mode

The EUP8090 enters the low-power sleep mode if AC-adapter is removed from the circuit. This feature prevents draining the battery during the absence of input supply.

### Internal Timer

The internal oscillator establishes a timing reference. The oscillation period is programmable with an external timing capacitor, $C_{TIME}$. The oscillator charges the timing capacitor to 1.5V and then discharges it to 0.5V in one period, both with 10μA current. The period $T_{OSC}$ is:

$$T_{OSC} = 0.2 \times 10^6 \times C_{TIME} \text{ (seconds)} \qquad (5)$$

A 15nF capacitor results in a 3ms oscillation period. The accuracy of the period is mainly dependent on the accuracy of the capacitance and the internal current source. The total charge time for the CC mode and CV mode is limited can be calculated as:

$$TIMEOUT = 2^{22} \times T_{OSC} = 14 \times \frac{C_{TIME}}{1nF} \text{ (minutes)} \qquad (6)$$

For example, a 15nF capacitor sets the TIMEOUT to be 3.5 hours. The charger has to reach the end-of-charge condition before the TIMEOUT, otherwise, a TIMEOUT fault is issued. The TIMEOUT fault latches up the charger. There are two ways to release such a latch-up: either to recycle the input power, or toggle the EN pin to disable the charger and then enable it again.

The trickle mode charge has a time limit of 1/8 TIMEOUT. If the battery voltage does not reach $V_{MIN}$ within this limit, a TIMEOUT fault is issued and the charger latches up.

### 2.8V Bias Voltage

The EUP8090 provides a 2.8V voltage for biasing the internal control and logic circuit. The maximum allowed external load is 2mA.

### Charge Status Outputs

The open-drain $\overline{\text{STATUS}}$ outputs indicate various charger operations as shown in the following table. These status pins can be used to drive LEDs or communicate to the host processor. Note that OFF indicates the open-drain transistor is turned off.
Table 1 summarizes the other two pins.

**Table 1. STATUS INDICATIONS**

| STATUS | INDICATION |
|---|---|
| High | Charge completed with no fault (Inhibit) or Standby |
| Low | Charging in one of the three modes |
| High | Fault |

### EN Input (Charge Enable)

The EN digital input is used to disable or enable the charge process. A high-level signal on this pin enables the charge and a low-level signal disables the charge and places the device in a low-power mode. A low-to-high transition on this pin also resets all timers and timer fault conditions.

### Input and Output Capacitor Selection

Typically any type of capacitors can be used for the input and the output. Use of a 0.47μF or higher value ceramic capacitor for the input is recommended. When the battery is attached to the charger, the output capacitor can be any ceramic type with the value higher than 0.1μF. However, if there is a chance the charger will be used as an LDO linear regulator, a 10μF tantalum capacitor is recommended.

### Current-Limited Adapter

Figure 22 shows the ideal current-voltage characteristics of a current-limited adapter. $V_{NL}$ is the no-load adapter output voltage and $V_{FL}$ is the full load voltage at the current limit $I_{LIM}$. Before its output current reaches the limit $I_{LIM}$, the adapter presents the characteristics of a voltage source. The slope $r_O$ represents the output resistance of the voltage supply. For a well regulated supply, the output resistance can be very small, but some adapters naturally have a certain amount of output resistance.

The adapter is equivalent to a current source when running in the constant-current region. Being a current source, its output voltage is dependent on the load, which, in this case, is the charger and the battery.

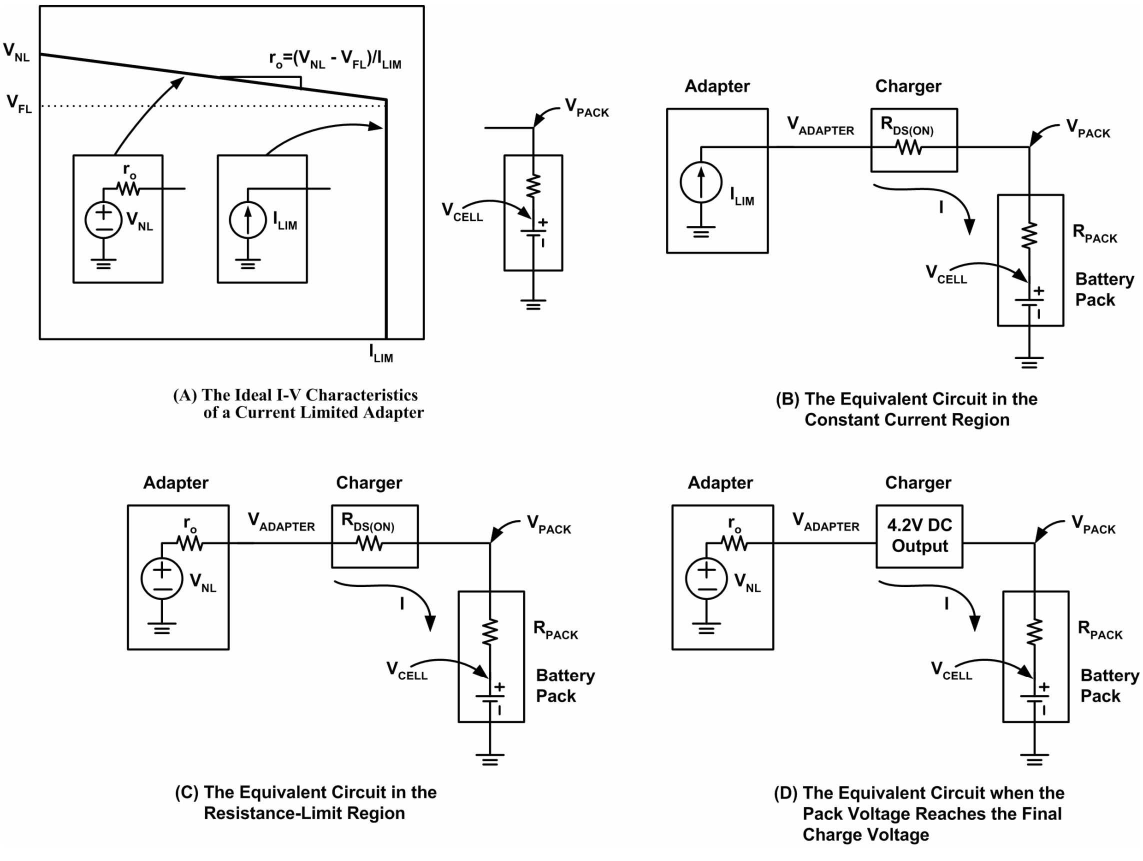
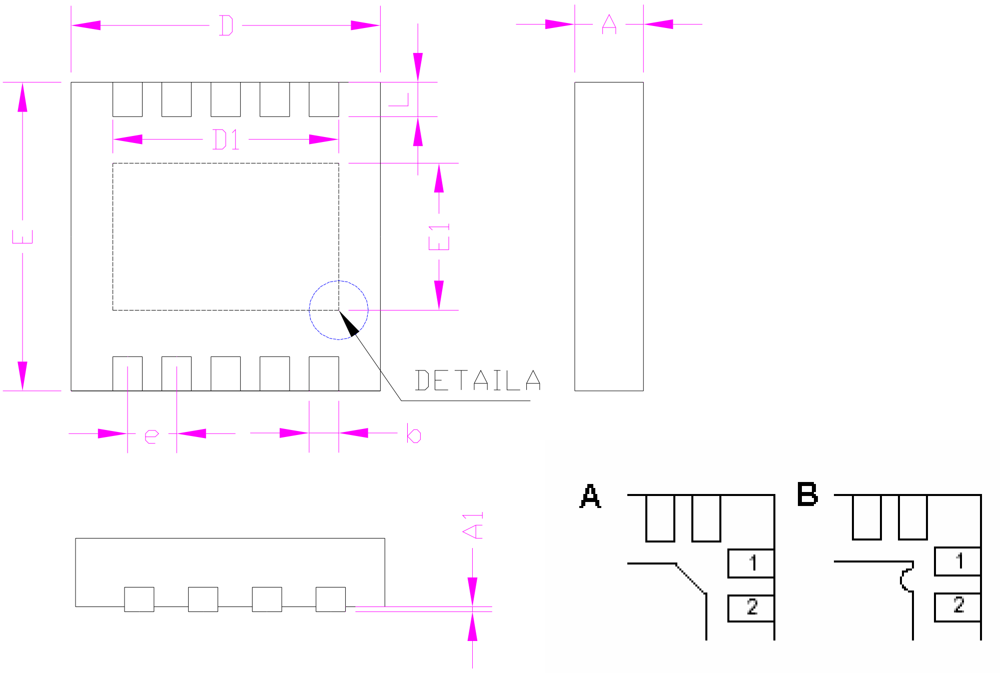



**Figure 22. The Equivalent Circuit of the Charging System Working with Current Limited Adapter**

## Packaging Information

**TDFN-10**




DETAIL A
Thermal Pad Option

| SYMBOLS | MILLIMETERS | | INCHES | |
|---|---|---|---|---|
| | MIN. | MAX. | MIN. | MAX. |
| A | 0.70 | 0.80 | 0.028 | 0.031 |
| A1 | 0.00 | 0.05 | 0.000 | 0.002 |
| D1 | 2.50 | | 0.098 | |
| D | 2.90 | 3.10 | 0.114 | 0.122 |
| E1 | 1.70 | | 0.067 | |
| E | 2.90 | 3.10 | 0.114 | 0.122 |
| L | 0.30 | 0.50 | 0.012 | 0.020 |
| b | 0.18 | 0.30 | 0.007 | 0.012 |
| e | 0.50 | | 0.020 | |
| D1 | 2.40 | | 0.094 | |